

Optimizing grouper catch efficiency using AI-controlled light fishing in Pamekasan

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Article Info

Article history:

Received May 16, 2025

Revised Feb 25, 2026

Accepted Mar 5, 2026

Keywords:

Artificial intelligence

Duty cycle

Grouper

Light fishing

YOLOv4

ABSTRACT

Light fishing techniques are widely used to improve marine fish catches by adjusting the spectrum and intensity of light-emitting diodes (LEDs) to attract specific species. Grouper (*Epinephelus* spp.) are known to respond well to red light, although the optimal light intensity remains unclear. This study proposes a dual system consisting of a pulse-width modulation (PWM)-based red LED brightness controller and an artificial intelligence (AI) fish detection module using the YOLOv4 algorithm. LED brightness was varied at duty cycles of 50, 100, 150, 200, and 250 (1 kHz), producing luminous flux values between 120 and 650 lm. Field experiments conducted at the Pamekasan coast using 10 grouper samples showed that 80% of fish aggregated at a duty cycle of 150 (~420 lm at 1.5 m). ANOVA results ($p < 0.05$) indicated significant differences among light intensities, with the highest attraction observed at this level. These findings suggest the existence of an optimal light intensity threshold. Further studies with larger samples and multi-site experiments are required to validate these results and evaluate ecological impacts.

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1. INTRODUCTION

Captured fish as a source of consumption is in demand by many people in various circles because in addition to good taste, captured fish has a high nutritional and protein content compared to farmed fish [1]-[3]. It is the growing human population in many countries in Asia, Africa, and South America that is primarily responsible for this growing demand for consumable fish, illustrating that a consistent source of fish is essential for the nutritional and financial health of a large portion of the world's population [4]-[6]. One of the environmentally friendly fishing techniques is to use light as bait [7], [8]. This technique is used by placing a light source in the area around the trap to increase the number of fish caught [9]-[11].

The use of artificial light has been widely applied by fishermen and fishing boats to invite fish to gather at the light source [12]-[14], the light source is usually placed in the area around the trap that has been set by the fisherman before, the use of light as artificial bait has been proven to provide more fish catches than just using traps alone, this method is commonly referred to as light fishing [15]. In its application, there are many light sources used as artificial feed, light sources can be torches, filament lamps, halogen lamps, metal halide lamps, and light-emitting diodes (LEDs). LEDs are currently the most widely used light source because LEDs are more energy efficient and easy to select the appropriate color [16]-[20]. However, the use of static light sources without control has an impact on catches that do not match the target due to the different

habitats and phototaxis properties of each type of fish [21]-[25]. So, it is necessary to add a fish counter system and LED control to the application of light fishing.

While artificial light has been shown to improve catch rates, its ecological impacts require careful consideration. Light attraction may alter natural fish behavior, increase bycatch, and affect nocturnal reef ecosystems. Therefore, ethical aspects such as research permits, bycatch mitigation, and alignment with local fisheries management policies must be addressed to ensure sustainable application. This research develops an LED brightness control system to adjust the number of fish gathered in the light source area. Utilizing artificial intelligence (AI) to detect fish gathering will help obtain accurate data. In this final project, technology was designed to collect grouper using LED light. The color of the light emitted by the LED will be adjusted to suit grouper, namely yellow light. The intensity of the light will be adjusted based on the number of grouper gathered, with differences in light intensity attracting different grouper. This research aims to determine the optimal light intensity for collecting grouper within the light beam area.

2. METHOD

This study followed a systematic research method, including literature review was conducted by searching for sources related to light fishing used to increase fish catch, high-power LED control systems, the use of pulse-width modulation (PWM) on Atmega328p, object detection using YOLO, and the implementation of YOLO on Jetson.

Observation to obtain an overview of the current fishing process. The observations yielded data on fishing methods, target catches, and catch quantities, controller design, and AI installation. Tests involved AI accuracy, LED intensity, and grouper characteristics.

YOLOv4 was used in the research because YOLOv4 is known for its ability to perform object detection quickly and efficiently, even in real-time conditions. YOLOv4 is capable of detecting small or overlapping objects within a single frame, a common characteristic in underwater environments, especially when many fish gather around a light source. This makes YOLOv4 highly suitable for detecting fish under limited lighting and visibility conditions.

After determining the final design of the system to be built, it is necessary to select components that meet the specifications so that the system can run according to plan. Component selection is divided into two categories: components for the LED controller and components for the AI system for fish detection. The components used for the LED controller include a microcontroller, op-amp, IC driver, metal oxide semiconductor field effect transistor (MOSFET), and LED. The components used for fish detection in water include the Nvidia Jetson Nano and the Bpro AE 5 webcam.

Figure 1 shows the framework of the system made with the main power source from the battery then stabilized using a regulator to supply the controller, LED, and computer. The controller sends a signal to the LED to light up with a certain intensity to attract the grouper to approach the light source, the camera sees the grouper around the light source and then sends data to the computer that has been installed AI to be detected and counted.

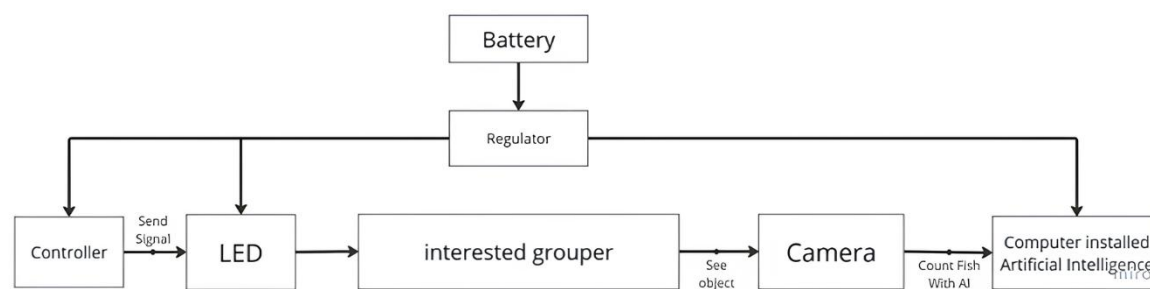


Figure 1. System framework

2.1. Planning power supplies, controllers, and computers

Controller planning is adjusted to LED strip type 5050 with a working voltage of 12 V, and for regulators adjusted to the power supply needs for computers, LEDs and controllers, considering that the battery voltage used is 16 V while the need for controllers and computers is only 5 V with a current consumption of 6 A, then for LEDs using a voltage of 12 V with a current consumption of 4 A, the regulator used must have the appropriate voltage specifications and a current that exceeds the needs of the components [20]. The

computer uses jetson nano because it has a portable size and has a lot of support in the form of hardware, and specialized libraries to run AI with an average frame rate above 21 frames per-second [26].

3. RESULTS AND DISCUSSION

At this stage, the design and testing results are discussed, empirical data is collected to validate the performance of the device, and analyses are conducted to draw conclusive conclusions.

3.1. Regulator and controller design

To optimize the dimensions and enhance the aesthetics of the controller board, an embedded system controller board was created that includes a buck converter and an Arduino Nano controller. The board design was created using Eagle, a widely used software program. The embedded system board design process began withdrawing the schematics for each component used (buck converter, Arduino Nano, and MOSFET wiring). Since the components used are open-source, the schematics for each component can be viewed officially on the original website of the component provider.

Before starting the PCB design of the regulator and controller, the first step is to collect schematic data from official sources related to the circuit you need. In the regulator design, the required voltage is 5 V and 12 V with a regulator current specification of 8 A, so based on the datasheet of several regulators, XL4016 is a type of regulator that suits the needs of the regulator.

Figure 2 shows the circuit scheme of the XL4016 regulator, the power from the battery is distributed through each VIN pin of the XL4019 regulator then the power is removed through the SW pin of the XL4019 regulator with the voltage adjustment of the FB pin, the FB pin functions as a voltage feedback to adjust the desired output voltage, this voltage setting is done by adjusting the resistance of the variable resistor (in the figure shown with R1 and R2).

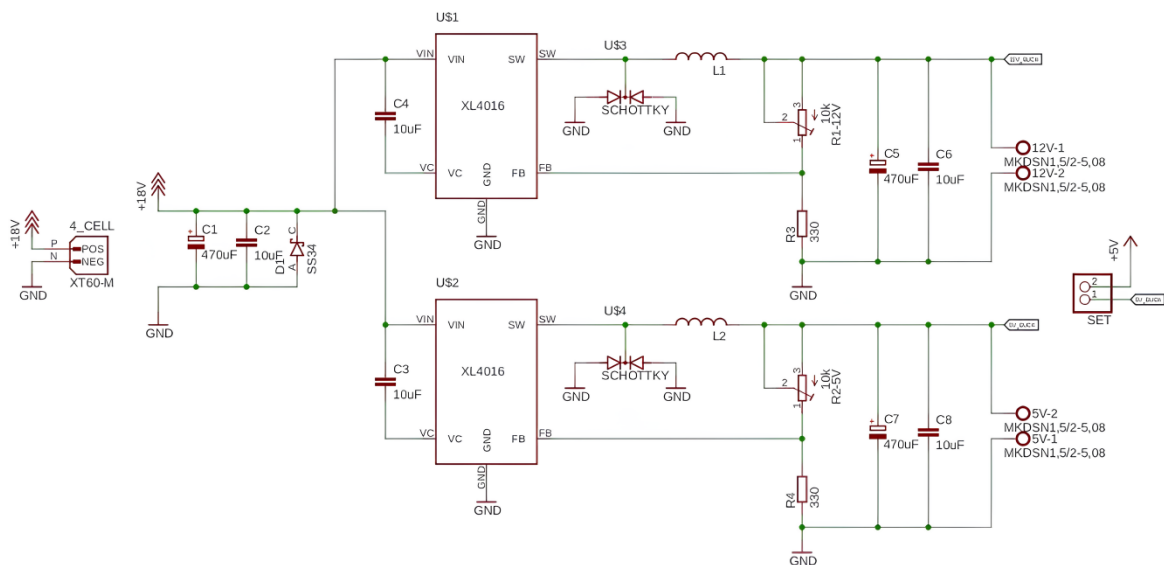


Figure 2. Schematic of the regulator

Figure 3 shows the scheme of the LED controller using atmega328p with a driver to the LED using a MOSFET with the type IRLZ44N, the brightness of the LED is regulated through a signal sent from pin PB2 to the MOSFET IRLZ44N, then the signal is used to adjust the duty cycle of the LED so that there will be a change in intensity [27].

3.2. Fish detection system design

This process begins with setting up Jetson Nano. The setup process includes installing Jetpack (Jetson operating system) and installing the necessary libraries and packages, such as Python, OpenCV, compute unified device architecture (CUDA), and CUDA deep neural network library (cuDNN). Data collection for training was carried out by taking videos showing grouper models. Video recording was conducted under various conditions, such as dim light, bright light, and underwater.

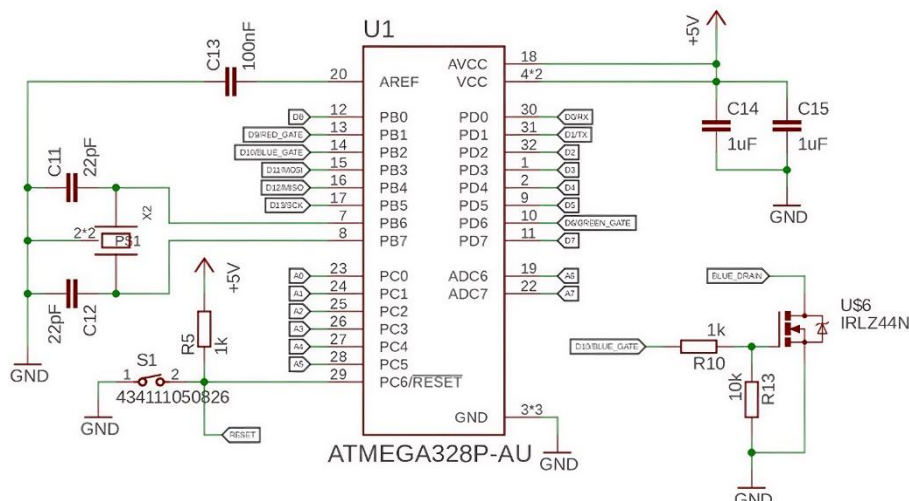


Figure 3. Controller schematic

To illustrate the hardware and software configuration used in this study, the setup process of the Jetson Nano development environment is presented. The system integrates a laptop for monitoring and control, the Jetson Nano board as the main processing unit, and peripheral devices including a wireless module for connectivity. As shown in Figure 4, the setup demonstrates the real-time interface displayed on the laptop screen alongside the connected Jetson Nano device and its supporting components.

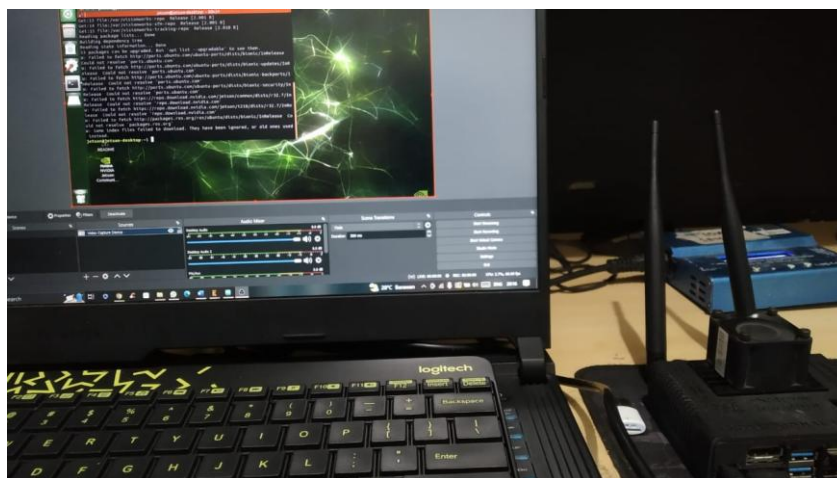


Figure 4. Jetson Nano setup process

3.3. Artificial intelligence design

Before the computer can recognise the specified object, the first step is to install the necessary packages and libraries such as CUDA, cuDNN and YOLOv4. CUDA is a parallel computing platform developed by NVIDIA. This package allows users to use a graphics processing unit (GPU) as a parallel processing unit for general computing tasks, including AI applications, while cuDNN is a software library developed by NVIDIA to accelerate AI operations on GPUs. Meanwhile, YOLOv4 is a popular and highly efficient real-time object recognition model.

In this experiment, approximately 7,700 images from frame extraction results were used. This was followed by a training process to obtain weight files that would later be used by YOLO as a reference model for detection. The fish detection system was trained on ~7,700 images extracted from underwater videos. To avoid frame leakage, dataset splitting was conducted by video: 70% training, 15% validation, and 15% testing. Data augmentation (rotation, brightness adjustment, and noise injection) was applied. Training was conducted on an NVIDIA Tesla P100 GPU with the following hyperparameters: batch size=64, epochs=200,

learning rate=0.001, optimizer=SGD with momentum 0.9. Performance metrics included precision, recall, F1-score, AP@0.5, and mAP@0.5:0.95.

Figure 5 shows the amount of data used to train the grouper fish model totaling 7,700 images and for validation totaling 56 images and for the testing set totaling 254 images. The images are divided into several parts, namely training, validation, and testing. The images in the training section will later be processed into filters in the weight file. The validation section is used to validate whether the filter matches the model, and the testing set is used to test the filter to obtain the detection accuracy value.

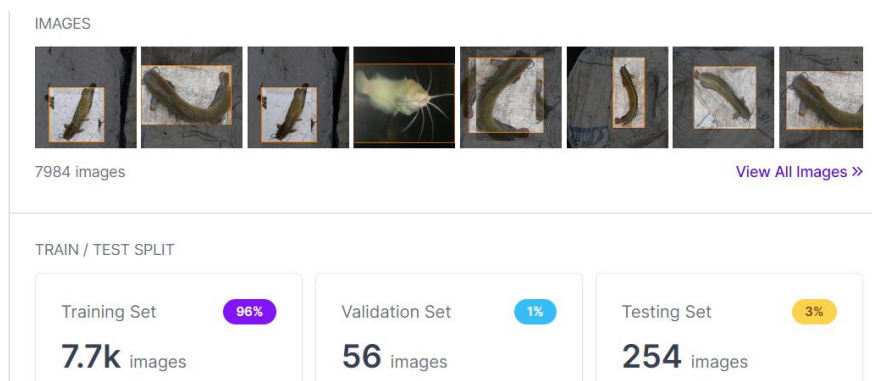


Figure 5. number of training data models

The need for accurate and consistent labeling processes on large datasets, such as the 7,700 photos in this study. The high amount of data requires significant time and resources for manual labeling, as well as the right augmentation and dataset division strategies so that the model can learn optimally without experiencing overfitting or underfitting. After the labeling process is complete, continue with the file configuration setup for the training process. Line 1058 in the configuration file is used to set the number of detection classes to be used. Since this final project only detects one object, only one class is used. After setting up the configuration file, the training process continues. The training process is not carried out on a local computer but using cloud computing, due to the limitations of the hardware used.

Demonstrating the command training section on the Kaggle platform using an Nvidia Tesla P100 GPU. The training process using the above dataset and configuration takes approximately 13 hours. The training process will produce a file in weight format, which contains the model parameters generated during the training process. After training, the model will be tested on fish.

To configure the object detection model, the parameter settings in the YOLO configuration file are presented. This figure illustrates the specification of key parameters, including the number of classes, anchor boxes, masks, and threshold values. As shown in Figure 6, the classes parameter is defined according to the dataset, which is essential for ensuring accurate model training and detection performance.

```

1054
1055 [yolo]
1056 mask = 3,4,5
1057 anchors = 12, 16, 19, 36, 40, 28, 36, 75, 76, 55, 72, 146, 142, 110, 192, 243, 459, 401
1058 classes=1
1059 num=9
1060 jitter=.3
1061 ignore_thresh = .7

```

Figure 6. Set the number of classes in the config file

To execute the training process of the object detection model, a series of commands are implemented within the training environment. This figure illustrates the use of a notebook interface to download pre-trained weights and run the training script using the YOLO framework with a custom dataset configuration. As shown in Figure 7, the command line includes parameters such as the dataset path, configuration file, and training options, which are essential for initiating and controlling the training process.



Figure 7. Command to perform training

Figure 8 shows the accuracy of the detection results. The YOLOv4 model demonstrates stable and accurate detection performance on grouper objects. The accuracy achieved in this image reinforces the claim that the model has an average detection rate above the minimum threshold of 50%, even approaching high accuracy (>80%).

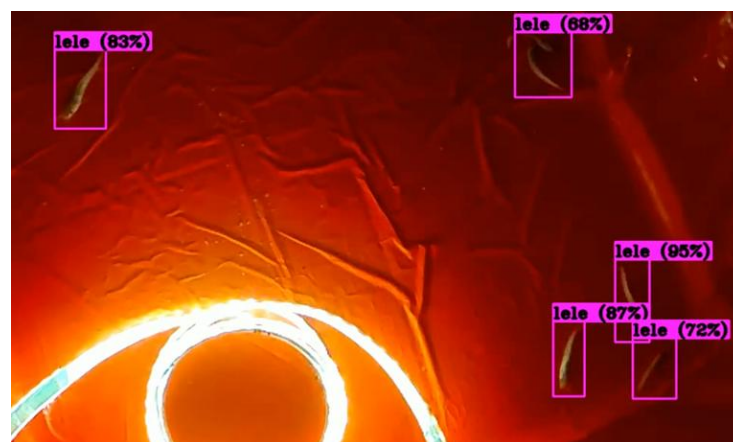


Figure 8. YOLOv4 detection results and accuracy

Fish counts were obtained using video footage recorded by a waterproof camera. A 30-second observation window was applied to avoid recounting the same individual. Manual annotations were validated by two independent observers (Cohen's kappa=0.87). These results demonstrate that YOLOv4 is suitable for application in light-based monitoring systems to optimize automatic fish capture.

The data is obtained from field observations, the data used is in the form of images that have been marked that the image is the object to be detected, the more examples of images used to train the model, the more accurate the detection of objects produced [26], [28], [29].

Figure 9 shows the mean average precision (mAP) graph or the accuracy of grouper object detection with the model that has been trained, the red line shows the accuracy rate obtained at each iteration, it can be seen that the accuracy rate has a good average accuracy above 80%.

The mAP graph shows that the average detection accuracy rate is above 80% in most iterations, indicating that the model has successfully learned the visual characteristics of grouper fish effectively. This proves that YOLOv4 is a reliable and efficient model for implementation in AI-based light fishing systems to enhance the efficiency of grouper fishing in the waters of Pamekasan.

3.4. System testing

Field tests were conducted on the Pamekasan coast at night. A randomized block design was applied, in which the order of duty cycle treatments was randomized each night. Each treatment lasted 30 minutes (25 min LED on, 5 min off), replicated over 5 nights at two sites. Environmental covariates including tide, moon phase, wind, temperature, and cloud cover were recorded. Two control treatments were included: i) no light and ii) static red LED.

Figure 10 shows a comparison of the test results, the red color graph at duty cycle 150 shows the highest fish attraction rate at 8 which means at the duty cycle it attracts 80% of the given fish samples, the highest numbers are located at iterations 3, 4, 5, 8 and 10, while at the highest duty cycle of 250, it only attracts 5 fish which means only 50% of the given samples, and for the lowest average is at duty cycle 50 with a

dominant value at 30%, this shows that there is an optimal intensity to attract grouper fish, not always with higher intensity will attract more fish [30], [31].

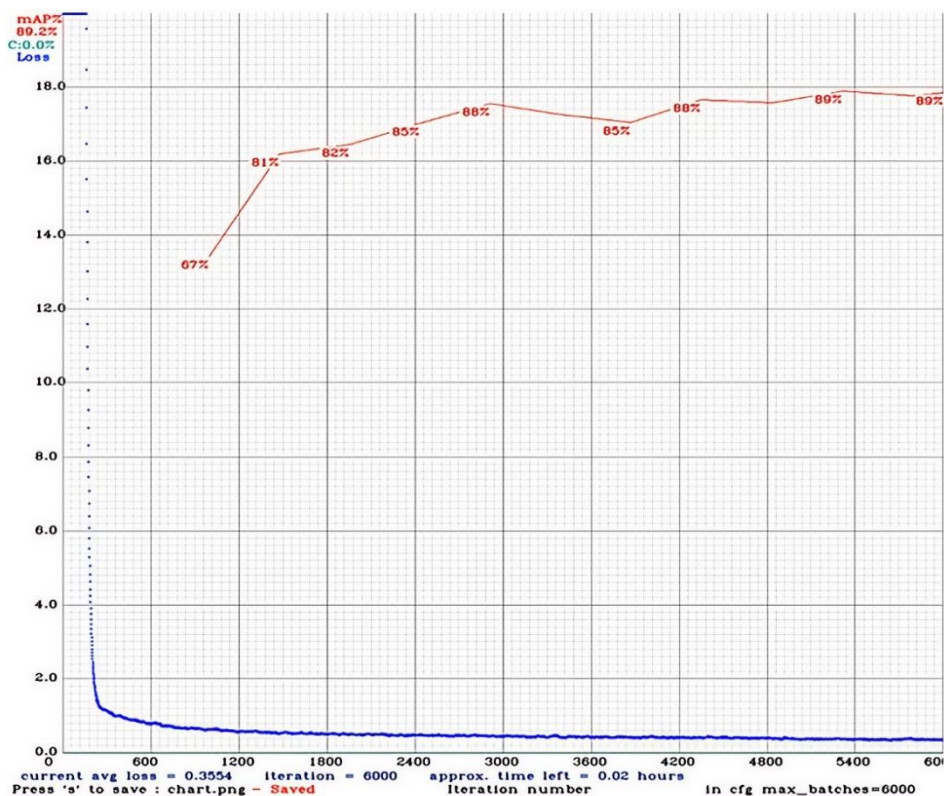


Figure 9. Object detection performance

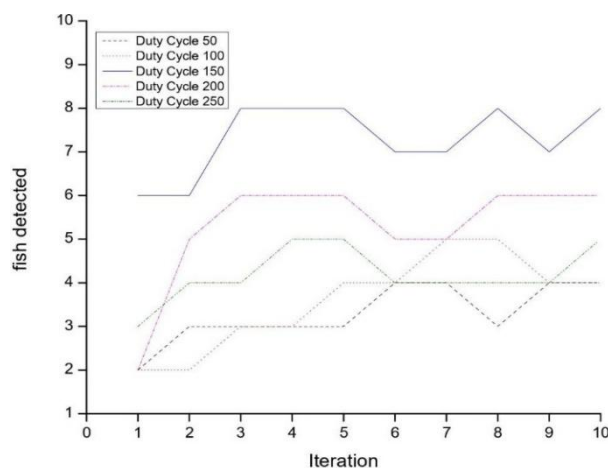


Figure 10. Comparison of test results

Although duty cycle 150 yielded the highest aggregation rate (~80% of samples), the small number of groupers tested (N=10) limits the generalizability of the findings. Larger trials with different species and life stages are required. Furthermore, ecological and ethical aspects must be considered, including potential disruption of reef ecosystems and bycatch risks. Research permits were obtained from local authorities, and care was taken to minimize handling stress on sampled fish.

In the light fishing research conducted by Yu *et al.* [32], they found that by using only red LEDs without control the results obtained were an increase in fish catches of around 58%, while in this study providing intensity variations to find the most optimal intensity and the optimal intensity has been found at

duty cycle 150 by attracting 80% of the fish from the sample that has been given. So, the intensity of catching grouper in this study attracted more than the previous studies.

4. CONCLUSION

From the planning and discussion process of the final project entitled “designing light fishing based on AI to obtain optimal intensity for attracting grouper,” it can be concluded that: i) a series of LED controllers capable of regulating yellow LED light with varying intensities using duty cycle variations of 50, 100, 150, 200, and 250 has been developed; ii) a grouper detection system using AI technology with the YOLOv4 platform has been developed, achieving an accuracy rate of over 50%; and iii) the intensity suitable for grouper characteristics has been determined to be the intensity at a duty cycle of 150.

This study demonstrated that an AI-based light fishing system can identify an optimal light intensity for attracting grouper (*Epinephelus* spp.). A red LED with a duty cycle of 150 (PWM, ~420 lm) resulted in the highest aggregation rate, attracting 80% of the tested samples. YOLOv4 achieved reliable detection accuracy with mAP>80%. However, due to the limited number of fish tested, the results should be regarded as preliminary. Future research should involve larger sample sizes, additional sites, randomized trials, and inclusion of ecological variables. Ethical considerations such as bycatch mitigation and sustainability must also be integrated before real-world application

FUNDING INFORMATION

This work was supported by Institut Teknologi Sepuluh Nopember under the Publication Writing and IPR Incentive Program (PPHKI).

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Mashuri	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	
Liza Rusdiyana		✓		✓	✓	✓			✓	✓				
Suhariyanto		✓		✓		✓			✓	✓		✓		

C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nterpretation

R : **R**esources

D : **D**ata Curation

O : **O**riginal Draft

E : **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data supporting the conclusions of this study can be provided by the corresponding author upon reasonable request. However, any data that might reveal participants' identities or sensitive information are not publicly accessible due to privacy considerations.

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